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# SALVAGING OF UNRIPE PROCESSING TOMATOES HARVESTED BY MACHINE



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# SALVAGING OF UNRIPE PROCESSING TOMATOES HARVESTED BY MACHINE

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## SUMMARY

Unripe processing tomatoes harvested by machine ripened to a satisfactory color during storage. Machine-harvested field-run lots ranging from mature-green to light-pink required about 10 days at 68° F. or 8 days at 77° for an 80 to 90 percent yield of ripe fruits. Machine-harvested mature-green fruits ripened faster than hand-harvested fruits. However, ethylene production by individual fruits was not influenced by method of harvest but only by stage of ripeness of the fruits. Treatment with ethylene (200 to 400 p.p.m.) for 2 to 4 days hastened the ripening of both mature-green and field-run tomatoes. However, its use would require reasonably airtight storage facilities, which would add to handling costs.

The incidence of decay varied greatly among lots. It averaged about 13 percent in tomatoes held in jars; it was usually lower in tomatoes held in lugs.

Salvage of 2 tons of initially unripe tomatoes per acre would yield about 300,000 tons of usable fruit with a farm value of $6 million in California alone. This fruit is now wasted.

## INTRODUCTION

About 180,000 acres of processing tomatoes were harvested in California in 1967. About 85 percent of this acreage was harvested by machine. Although machine harvesting of tomatoes is less common in the Eastern United States than in the West, undoubtedly the practice will increase in all parts of the country in the next few years.

Machine harvesting, a once-over operation, is usually done when 80 to 90 percent of the tomatoes are ripe and before too many of the tomatoes are overripe. However, late in the season almost half the tomatoes may be unripe at the time of harvest; consequently, a substantial tonnage of unripe fruit is discarded in the field each year. This waste could be reduced if the tomatoes could be ripened and then sold for processing. With an average yield of 20 tons per acre, salvaging the additional 10 percent of the crop that is now discarded would yield an additional 300,000 tons of tomatoes with a farm value of $6 million in California alone.

Collecting and ripening such large quantities of tomatoes present problems of physical handling and economic feasibility. However, before these problems could be critically evaluated, answers were needed to some of the biological questions involved: 1) would machine-harvested tomatoes ripen properly; 2) how rapidly would they ripen; 3) would ethylene significantly speed up ripening; and 4) would decay be a limiting factor? At the request of representatives of the tomato industry, some answers to these questions were obtained during the 1967 harvest season. One season's research in the laboratory is not sufficient to provide conclusive answers to all the problems involved.

[1]The authors are stationed in Fresno, Calif.

However, the results and the related discussion may help the industry determine the feasibility of salvaging unripe processing tomatoes.

Problems associated with the recovery of the unripe fruits on the harvester and the economics involved in ripening machine-harvested tomatoes for processing are not considered in this report.

## METHODS

The tomatoes used in these tests were grown in western Fresno County, Calif. They were harvested with FMC harvesters (Models 65-W or 66-W) from August through early November 1967. The varieties used were VF-145, 214 Select, and Mech 9. Unripe fruit was picked off the sorting belt of the harvester, placed in wooden boxes, and transported to the laboratory in Fresno. Handpicked fruits were harvested from a row near that picked by machine.

Mature-green fruits were used exclusively in some tests, but in others breaker and light-pink fruits also were included (8).[2] In the field-run lots the proportions of fruit in each ripeness class conformed to that in the original sample taken from the machine (about 75 percent mature-green, 15 percent breakers, 10 percent light-pink). In such tests each treatment initially contained an equal number of fruits from a given ripeness class and the fruits within each class were matched for color and size. The diameter of the fruit ranged from about 1 1/2 to 2 1/4 inches.

Each sample of 60 sound-appearing fruit was held in a glass jar at 68° F. (20° C.) for ripening. Air or 200 to 400 p.p.m. of ethylene in air was passed over the samples at a rate that kept the carbon dioxide concentration in the jars below 0.5 percent. Previous work (3) has shown that these concentrations of ethylene stimulate the ripening of tomatoes. The ethylene was dispensed from a cylinder containing 1 percent ethylene in nitrogen and was further diluted by mixing with incoming air through a glass T-tube. The samples were exposed to the desired gas mixture within 5 hours of harvest.

The tomatoes were examined after 5 to 8 days and again 2 or 3 days later. At each examination the fruits were separated into five color classes: mature-green, breaker, light-pink, dark-pink, and table-ripe or riper (8); and the percentage of fruit in each class was determined. The percentage of decayed fruits, regardless of color class, also was determined. The decay data given are the totals for both examinations.

The incidence of decay was determined also on tomatoes held in open, wooden boxes to simulate conditions encountered in commercial practice, where the fruits are harvested into bins. The boxes were covered with ventilated polyethylene bags to prevent excess moisture loss from the fruits. These tomatoes were examined concurrently with the second examination of the lots held in jars.

Each experiment was carried out at least twice and the results were tested by an analysis of variance. The percentages were transformed to logarithms for analysis and their antilogarithms are presented. The data from each examination were analyzed separately, because the same fruits were examined each time.

Detailed methods applying to specific tests will be given in the relevant results sections.

[2] Underscored numbers in parentheses refer to Literature Cited, p. 7.

## EFFECT OF METHOD OF HARVEST ON RIPENING

### No Ethylene Added

Mature-green tomatoes picked by machine ripened more rapidly than those picked by hand (fig. 1, A). Five times as many machine-harvested fruits as hand-harvested fruits were table ripe (25 percent and 5 percent, respectively) after 5 or 6 days at 68° F. After 2 additional days, 55 and 35 percent were ripe, respectively. The slower ripening of the handpicked lots was emphasized by the large proportion of handpicked fruit remaining in the mature-green class even after 7 or 8 days.

### Ethylene Added

Ethylene applied during the first 4 days of storage accelerated the ripening of the mature-green tomatoes regardless of method of harvest (fig. 1, B). However, after 5 or 6 days, ethylene had speeded up the coloration of hand-harvested

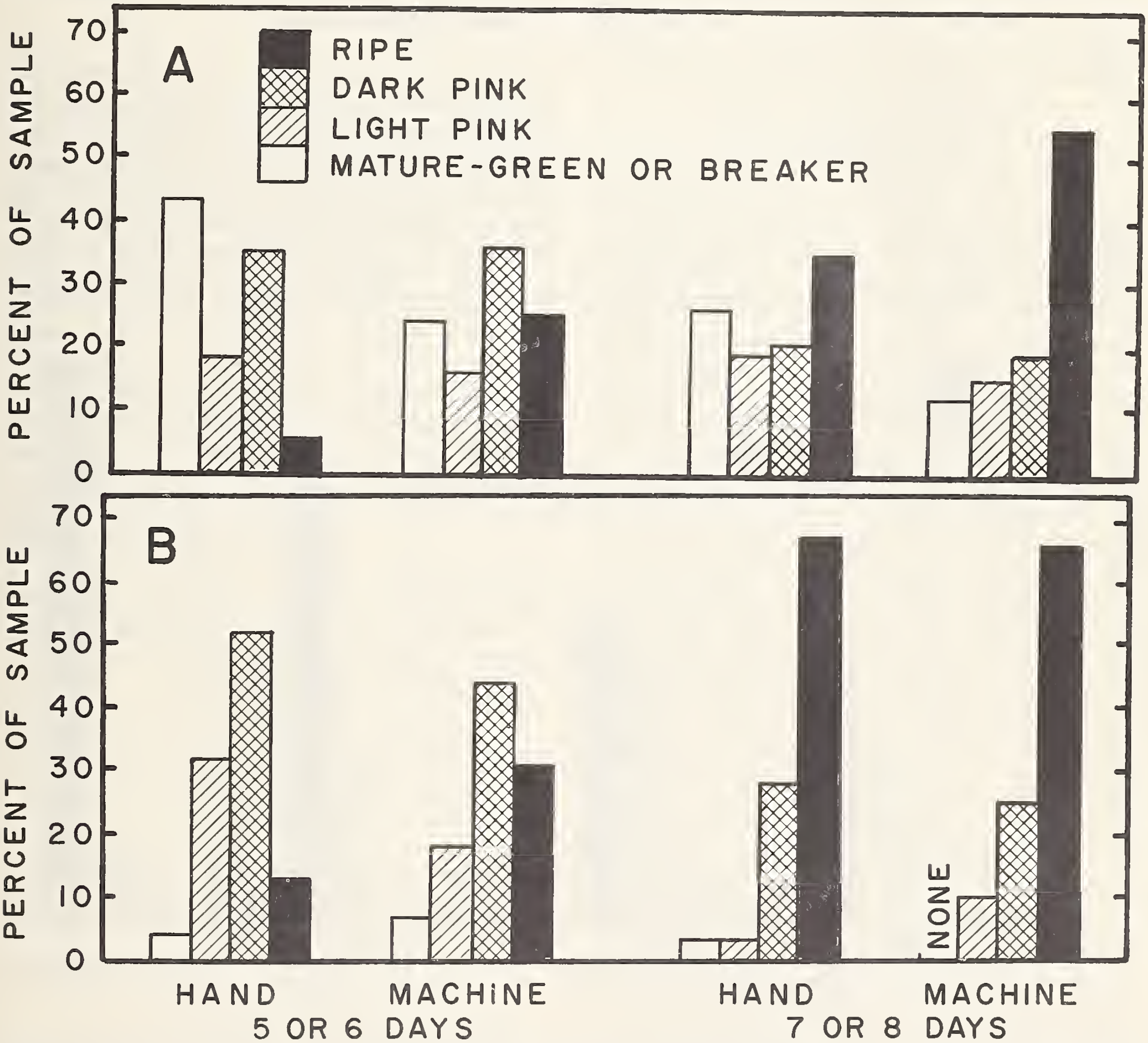


Figure 1.—Effect of method of harvest and of ethylene on the ripening (at 68° F.) of mature-green tomatoes: A, Ripened without ethylene; B, Ripened with 200 to 400 p.p.m. ethylene in the atmosphere during the initial 4 days of storage. (Days shown are number of days tomatoes were held for ripening before examination.)

fruit more than it had machine-harvested fruit. (Compare fig. 1, A and 1, B.) Nevertheless nearly three times as many machine-harvested as hand-harvested fruit were ripe at this time. Two days later, however, this difference had disappeared and both lots were equally ripe.

Since essentially all fruit that were at least light pink after 7 or 8 days would be fully ripe after 10 days, machine-harvested lots treated with ethylene would yield 100 percent ripe fruit and those not exposed to ethylene would yield 90 percent; the corresponding yields for hand-harvested fruits would be 97 percent and 75 percent.

There was no obvious difference in the color or firmness of ripe fruits that could be attributed to method of picking or ethylene treatment—all fruits were deep red and firm.

## ETHYLENE PRODUCTION BY TOMATOES

Individual machine- and hand-harvested tomatoes produced about equal amounts of ethylene when they were at the same stage of ripeness. This result and the data on ripening indicate that the increased ethylene production associated with ripening occurs earlier, but is no greater in machine-harvested fruits than in hand-harvested fruits. This change is most likely induced by the severe vibrations associated with machine harvest. Ethylene production ranged from 2 to 133 microliters per kilogram each 24 hours as the fruits changed from mature-green to ripe. These values are similar to those reported by Lyons and Pratt (4).

## EFFECT OF ETHYLENE ON RIPENING

### Mature-Green Tomatoes

The rate of ripening of mature-green fruit harvested by machine was investigated further to determine more definitely potential benefits to be derived from exposure of the tomatoes to ethylene. Fruit exposed 4 days to 200 to 400 p.p.m. ethylene ripened faster than the control (no-ethylene treatment) fruit (fig. 2). Although

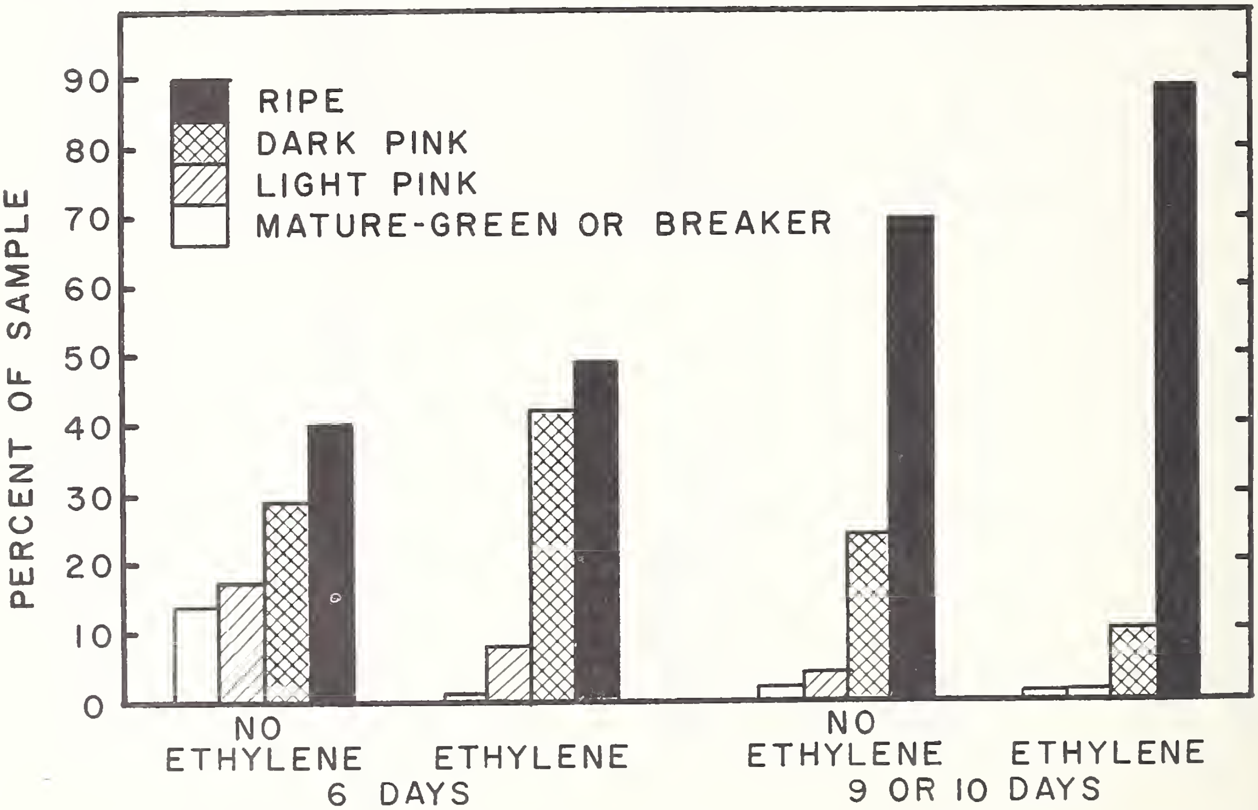


Figure 2.—Effect of ethylene on the ripening (at 68° F.) of machine-harvested mature-green tomatoes. Ethylene lots treated with 200 to 400 p.p.m. of the gas during the initial 4 days of storage. (Days shown are number of days tomatoes were held for ripening before examination.)

the difference in the proportion of ripe fruit was only slight after 6 days at 68° F., it was statistically significant at the 99-percent probability level after 9 or 10 days. At the latter examination 89 percent of the fruits treated with ethylene were ripe, but only 70 percent of the controls were ripe. The acceleration of ripening due to ethylene was again (see fig. 1) most pronounced during the last 3 or 4 days of the storage period, even though the ethylene was applied only during the initial 4 days. Ethylene affected the rate of ripening, but it had no effect on the potential yield of ripe fruit; almost no mature-green fruit were left in either treated or control lots at the second examination (fig. 2).

### Field-Run Tomatoes

In commercial practice, field-run lots that include breaker and light-pink fruits would be ripened rather than lots composed solely of mature-green fruits. Consequently, 200 to 400 p.p.m. ethylene was applied to such lots of tomatoes for 0, 1, 2, or 3 days to determine whether the gas would accelerate ripening of these fruit as it had done with lots of mature-green fruit.

The effect of the ethylene treatment on ripening was not evident after 8 days at 68° F., but after 2 additional days lots of fruit that had been treated for 2 or 3 days with ethylene had significantly more ripe fruit than those held without added ethylene:

| Duration of ethylene treatment, days: | Ripe fruit after 10 days |
|---|---|
| | Percent[1] |
| 0 | 78 a |
| 1 | 86 ab |
| 2 | 88 b |
| 3 | 89 b |

[1] The percentage figures with different letters differ statistically at the 99-percent probability level.

### Discussion

Although ethylene does hasten ripening of mature-green and of field-run lots of tomatoes harvested by machine, the practicality of its use is doubtful. Its use would require reasonably airtight storage facilities, which would add to the handling costs. Consequently, treatment with ethylene precludes using evaporative coolers during the 2 to 4 days required for treatment, because of the large quantity of fresh air that is introduced by this method of cooling. Therefore, more costly mechanical refrigeration would be required. If, however, more than about 90 percent of the fruits to be ripened are initially mature-green and if the ambient temperatures are relatively low the use of ethylene may be justified. Under such circumstances, mechanical refrigeration may not be needed and ventilation could be kept minimal until after the treatment.

## TEMPERATURE AND TIME REQUIREMENTS FOR RIPENING

Tomatoes ripen satisfactorily between 55° and 80° F., with 75° being the optimum for speed of ripening and development of desirable color (5). Prolonged exposure to about 85° or higher temperatures slows the rate of ripening and results in orange-yellow fruit (5, 7). However, work in Florida (2) has shown that exposure of tomatoes to 90° to 100° is harmless if that exposure is limited to 8 hours per day and the fruit is held at about 68° during the remaining 16 hours of the day. These findings suggest a practical solution to the problem of achieving desirable color at the speed required for ripening large quantities of machine-harvested fruit. In a hot, dry climate bins of unripe tomatoes could be placed in permanent or temporary enclosures cooled by evaporative coolers. With outside daytime temperatures between 90° and 100° and the relative humidity below 30 percent, it would be possible to maintain the storage below 80° most of the time. (The average dew point is usually between 50° and 60° in the San Joaquin Valley from August through October.) When the air temperature drops below 70° at night, dry outside air could be blown through the storage area. During late October, dry outside air may be sufficient even during the day. In areas where evaporative coolers are ineffective, mechanically refrigerated storage might be required to ripen the tomatoes. However, air movement adequate to dissipate

the respiratory heat produced by the ripening tomatoes would be needed in either type of storage. (See Appendix for rates of heat production.)

With proper temperatures, how long will it take to ripen machine-harvested tomatoes? When mature-green fruit was held at a constant 68° F. (20° C.), 70 percent was ripe after 10 days (fig. 2). Assuming a temperature coefficient ($Q_{10}$) of 2 (from the data of Wright and others (9)), it was found by the van't Hoff rule (see Appendix) for calculating reaction rates that at 77° (25° C.) 98 percent of the fruit would have been ripe after 10 days. For field-run lots the corresponding values would be 78 and 109 percent. This theoretical result indicates that at 77° fewer than 10 days are required to ripen all the fruits. Waiting for all fruits to ripen would be impractical, however, because of limitations in storage space and because of the inroads of decay. Consequently, the time required to achieve a 90 percent yield would be more realistic. This goal could be achieved by storing the tomatoes 8 days at 77°, if the theoretical yield of 109 percent after 10 days is taken as the basis for calculation. These estimates of percentages and times are approximate only; response might be influenced by such factors as variety, proportion of fruit in each ripeness class initially, and variations in temperature in the storage area and within bins.

The ripening time might be shortened by the use of ethylene. However, no exact prediction can be made regarding this acceleration of ripening, because the response of tomatoes to added ethylene may be less at the higher temperature at which the fruits themselves produce more ethylene than at 68° F. (1).

## EFFECT OF SEASON OF HARVEST ON RIPENING

There was no apparent effect of season on the rate of ripening. Fruit harvested early in November ripened as rapidly as that harvested late in September. However, this situation may be atypical, because daytime maxima in October 1967 were frequently 3° to 6° F. above normal and the minima were near normal. In years when normal day and night temperatures occur, field chilling may be a hazard late in the harvest season. Further, late in the harvest season a larger proportion of the fruits is unripe than early in the season. In some cases one-third to one-half of the crop was discarded because of unripe fruit. Recovery of this large part of the crop by postharvest ripening would seem desirable. This practice would also allow earlier harvest and, therefore, major losses from rain or cold would be avoided.

During the early, warm part of the season, tomatoes are harvested when 80 to 90 percent are ripe. However, harvesting when only 70 to 80 percent are ripe might be advantageous if internal sprouting of seeds becomes a major problem (10). This disorder occurs in tomatoes that have remained on the plant for some time after the fruit has reached full color. The sprouted seeds appear as foreign matter in the processed tomatoes. Earlier harvesting and ripening unripe fruit after harvest would minimize this economic loss.

## INCIDENCE OF DECAY

The incidence of decay in the lots held in jars varied greatly from test to test and even between replications in the same test. Further, there was no relation between decay and ethylene treatment. The incidence of decay in individual jars ranged from 0 percent to 83 percent and averaged 13 percent. Decay usually was less common in tomatoes held in lugs, where the relative humidity was lower than it was in the jars. In one lug, however, moisture condensed on some fruits and about 80 percent of the tomatoes were decayed. It seems, therefore, that from 10 to 20 percent of the fruit may decay during ripening and that lower or higher losses may occasionally occur.

The optimum temperature for ripening tomatoes also favors rapid growth of Rhizopus, the chief cause of decay in our tests. Decay also was influenced by two other factors–injury to and shape of the tomato. The lack of decay in mature-green, hand-harvested fruit when ripened and the incidence of 2 to 9 percent decay in machine-harvested fruit demonstrated the effect of injury on decay. The effect of fruit shape on decay is evidenced by the number of infections at the blossom end, which was very pointed in much of the test fruit. Pointed fruit is easily injured during machine harvesting and becomes infected.

With some decay almost inevitable, the tomatoes will undoubtedly have to be sorted after ripening and before they are hauled to the cannery. Fruit that failed to ripen could also be removed at this time.

## SORTING BY RIPENESS AND QUALITY DURING HARVEST

Sorting unripe fruit for degree of coloration on the harvester would probably be physically impossible because of the large volume of fruit. Even if possible, it would be undesirable because field-run lots ripen slightly more rapidly than lots of exclusively mature-green fruits when they are not treated with ethylene. Further, there is little danger from excessive softening of the initially pink fruit, because current varieties of processing tomatoes remain firm even when ripe. Consequently, only small (less than 1 1/2 inches in diameter) and obviously injured fruits should be culled. The small fruits often fail to ripen, and the injured fruits would be potential centers of decay during ripening.

## CONCLUSIONS

Ripening of unripe processing tomatoes harvested by machine is possible, but the success of the procedure will depend largely on

1. Success in solving the problems associated with the sorting and handling of unripe fruit on the harvester,
2. Maintenance of proper temperatures during ripening,
3. Minimizing the incidence of decay.

Electronic color sorters and associated equipment may help solve the problems of sorting and handling. The other two problems cannot be fully evaluated until there is some commercial application of postharvest ripening of machine-harvested tomatoes.

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## APPENDIX

A. Calculation of rate of ripening from temperature coefficient ($Q_{10}$) by the van't Hoff rule:

$$Q_{10} = \left( \frac{K_2}{K_1} \right)^{\frac{10}{t_2 - t_1}}$$

where $K_2$ and $K_1$ are reaction rates (percentage of fruit ripe on a certain day, or number of days to a certain percentage of ripe fruits) at temperatures $t_2$ and $t_1$, given in ° C.

B. Heat production of ripening tomatoes at several temperatures (data from (6)):

| Temperature, ° F.: | BTU per ton each 24 hours |
|---|---|
| 60 | 5,900 |
| 70 | 8,900 |
| 80 | 10,600 |
| 90 | 14,900 |

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